



Lesson: Failures are not an option, they are fact.

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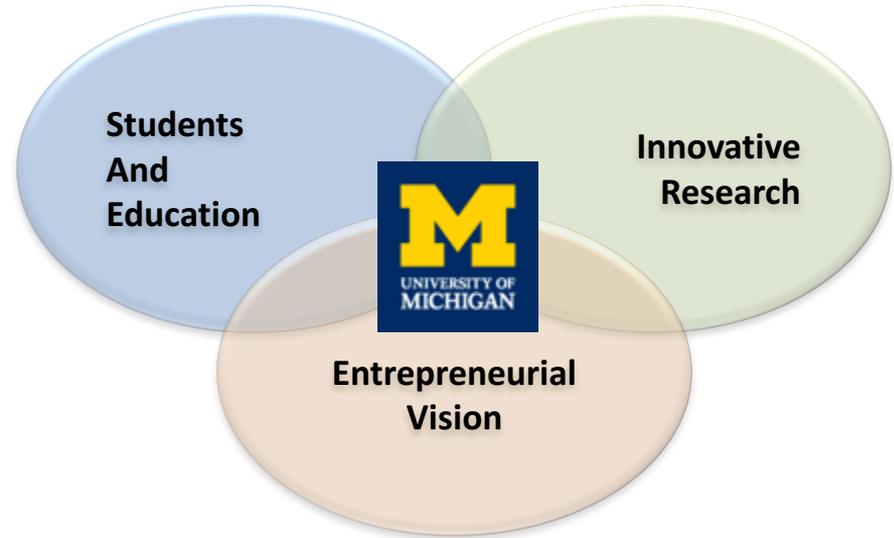
... a university-based research lab centered on flight.

MXL: Michigan Exploration Lab

- Research-driven flight lab
- Faculty directed
- Engineers, Grad and U-grad students
- Access to NASA certified technicians

- 6 sats on orbit, 5 in the queue

Bold flight to the extremes...



Small sats have at least 5 degrees of freedom.

1. Dimensions
2. Budget
3. Schedule
4. Team
5. Programmatic



Note—small sats are *not* new.



Photo: Public Domain



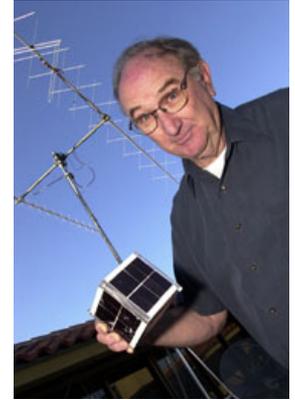
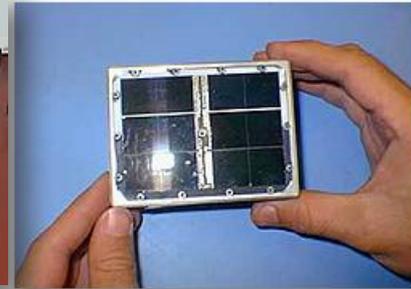
Photo: SSTL

Ridenoure, R. W. and Jones, R. M., “**Microspacecraft for Planetary Missions: Recent Technology Developments**”, 19th International Symposium on Space Technology and Science, Yokohama, Japan, May 15-24, **1994**.

Janson, Robinson, Helvajian, The Concept of '**Nanosatellite**' for Revolutionary Low Cost Space Systems," presented at the 44th International Astronautical Federation Congress in Graz, Austria, in **1993**.

1999, CubeSat recipe and ingredients?

U's + JPL + DARPA + HAMs+ Internet = CubeSats



Even our successful missions have had failures.

Mission	Sponsor	Dates	U	Status
RAX-1	NSF	2010-11	3	Payload checkout. Solar panel failure due to design flaw. 3U
RAX-2	NSF	2011-13	3	Full mission success. SD card failure. Unknown end of mission reason.
MCubed-1	NASA ESTO	2011 -	1	Physically docked to E1P (1U). Beacon outputs but not commandable.
MCubed-2	NASA ESTO	2013 -	1	Full mission success. SD card failure. Satellite quiet for several months. Back again.
GRIFEX	NASA ESTO	2014 -	3	Full mission success. SD card failure.
CADRE	NSF	2016	3	Powered on, no beacons or uplink. Deorbited.

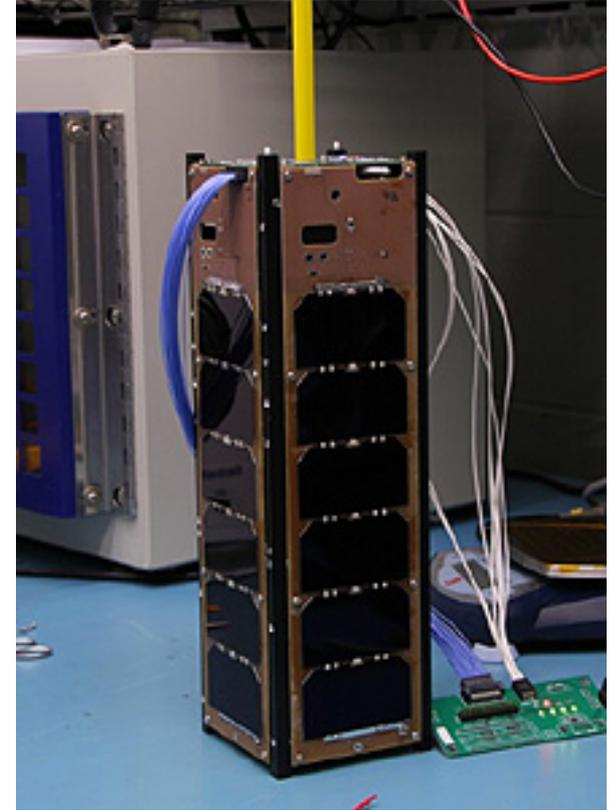
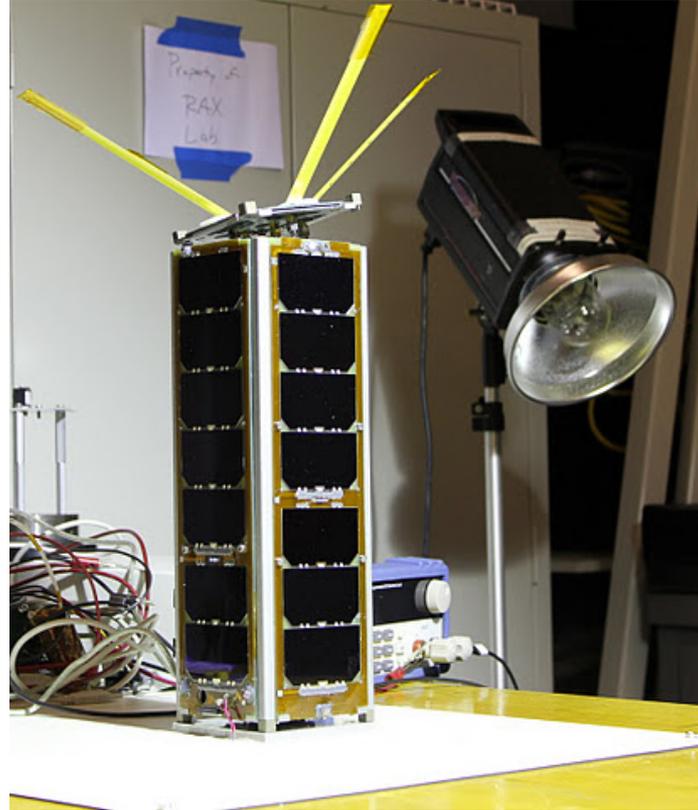
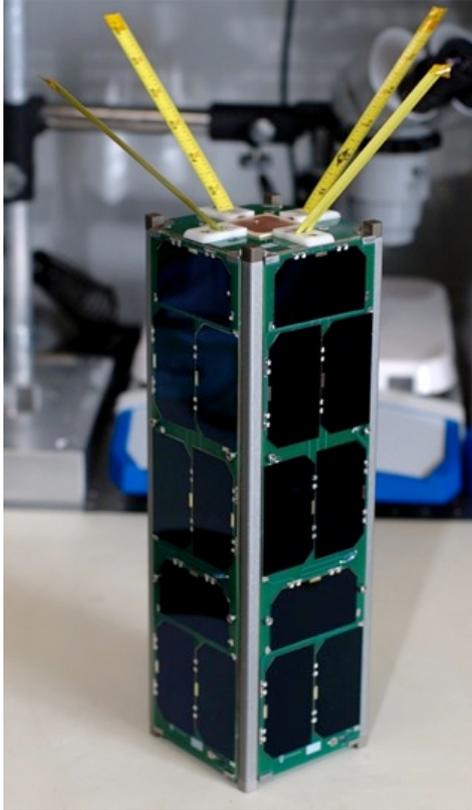
Lesson: If it looks odd, it's probably bad.
Explain everything.



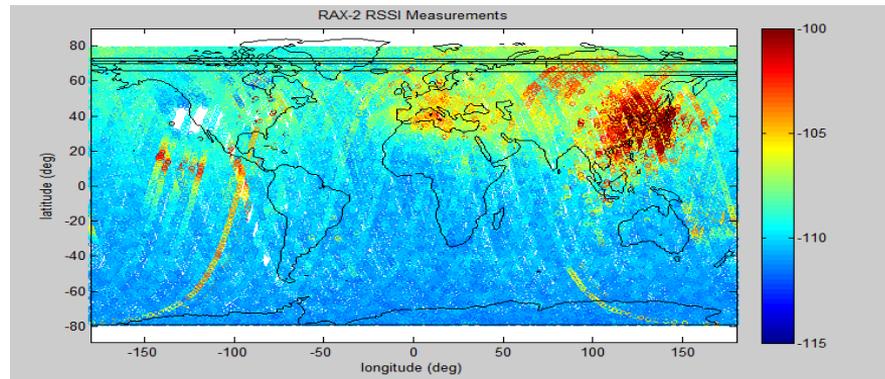
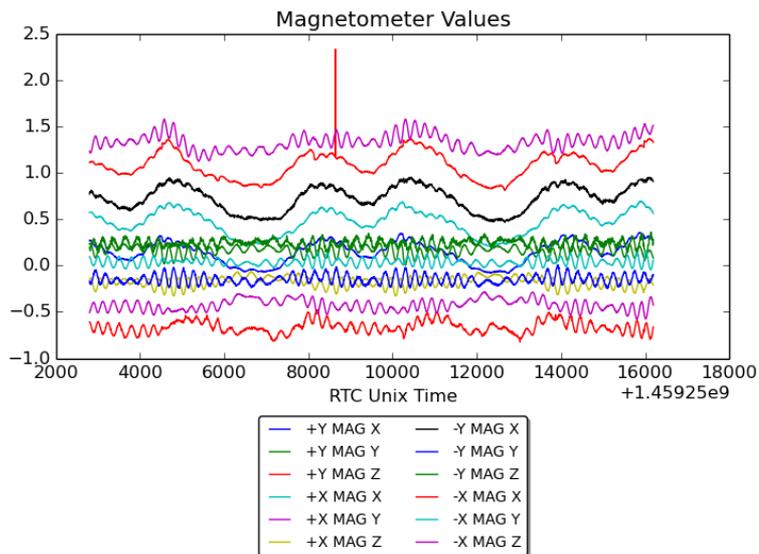
Lesson: Formalize as much as you can,
know why, but be prepared to compromise.



Lesson: Follow flight rules – Technician vs engineer



Lesson: Operations is typically the last thing teams think about, and that's not good.



Think big data.
We need access to data.

Many components impact robustness.

Parts



Design

Many components impact robustness.

Parts



Design



Processes



Team

Policy?

Can we enable “**organic robustness**”?



cycles / rhythms / stability / healing

Let's build a **sustainable** foundation: educationally-inspired, research-driven flight **labs**

Blimps ...

Hoovercraft ...

Balloons ...

Space missions



Organic robustness can be a pillar...



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